INTERNATIONAL JOURNAL
OF
CONSERVATION SCIENCE
ISSN: 2067-533X Volume 10, Issue 4, October-December: 773-780 www.ijcs.uaic.ro

PLANT SPECIES GROWING IN LATERITIC SOIL WITH ORNAMENTAL POTENTIAL FOR MINED LAND REHABILITATION

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Abstract

Mine rehabilitation planning involves identifying plant species that can survive in the lateritic soil which is rich in nickel and iron but poor in the major nutrients. Thus plant species growing in the disturbed and undisturbed areas of the nickel mine were assessed. Thirty different species in the disturbed and undisturbed areas were identified and found to be highly tolerant of soil rich in nickel and iron content. Pteridium aquilinum, Saccharum spontaneum, and Imperata cylindrica were the most dominant species in the area based on presence in the various elevations of the mine site. The plant analysis, however, revealed Crypteronia paniculata and Leucosyke capitellata to have the highest content of nickel and iron. These two species have potentials for use as ornamental plants. These species can, therefore, be integrated into the mine rehabilitation program for eco-restoration and livelihood among people in the host communities.

Keywords*: Mine rehabilitation; Ornamental plants; Laterite; Mined land; Ecosystem restoration*

Introduction

Mine rehabilitation is crucial in nickel mining to restore the vegetation after stripping the soil surface of vegetation. Rehabilitation is the process to restore the ecological integrity of the disturbed mined lands. It includes the management of the physical, chemical and biological aspects of the soil such that the soil fertility, microbial community, and various soil nutrient cycles are restored. In planning mine rehabilitation, technologies in planting and landscape architecture are necessary especially if the end use plan of the area is for ecotourism. Likewise, plant species to be used for rehabilitation must be known to optimize the rehabilitation program particularly in providing livelihood to the communities when the mine finally closes. A review was conducted on the technical, scientific and ethnobotanical literature on traditional uses and recently discovered uses of selected plant species in Chile and found that 68 naturally colonizing phytostabilization species have at least one known use [1]. There are 420 species with various uses and have the potential for use in phytostabilization, thus can be valuable phytogenetic resources in the rehabilitation of massive mine wastes. Planning for the life after mine closure is one of the critical activities required for mining companies to consider. Livelihood sources such as the development of enterprises are vital to the local communities' survival when the mine closes. Bush products provide one of few prospects for new or

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expanded natural resource-based enterprise activity by indigenous people of remote regions of arid central and tropical northern Australia [2]. By developing natural resource-based enterprises, livelihood provision can be sustained even after the mine.

Vegetation plays an important role in providing habitat to biodiversity and protecting the soil surface from wearing away [3]. The vegetation increases soil organic matter from the litterfall, lower the bulk density, and regulate soil pH and bring mineral nutrients to the surface [4]. The revegetation of mined-out areas, therefore, is a necessary step to bring back the ecosystem to where it was before mineral extraction was done. The revegetation of the eroded ecosystems is carried out with plants selected by their ability to survive and regenerate or reproduce under severe conditions [5, 6, 7]. Drought-resistant, fast-growing crops or fodder which can grow on nutrient deficient soils is the most important to consider in choosing plants for mine rehabilitation. Plant species with high survival capacity and have a dense canopy that modifies the microclimate have been identified to attract birds and insects that can naturally disperse plant seeds in the mined land [7]. Selected plants must also be tolerant of heavy metal contaminants in the area [8, 9]. Plant species with potential to be cultivated for ornamental purposes are also good candidates in mine rehabilitation. Ornamental plants are playing an increasingly important role in urban habitats throughout the world. As many ornamentals are not edible, the risk of contaminants from mining areas entering the food chain is reduced. Ornamental plants are important in cleaning up the environment [10].

Moreover, they have the added advantage of enhancing the environment's aesthetic besides generating additional income opportunities for the local communities. This is especially necessary when the life of the mine has ended, and the local communities have to shift their livelihood source. It is with this premise that identification of ornamental plant species existing in lateritic soils was conducted. Species of ornamental plants that grow in the various elevations of the mountain with lateritic soil were identified, and the presence of nickel and iron was analyzed.

Methodology

The study was conducted in the nickel mining area of San Roque Metals Incorporated (SRMI) in Caraga Region, Philippines (Fig. 1.).

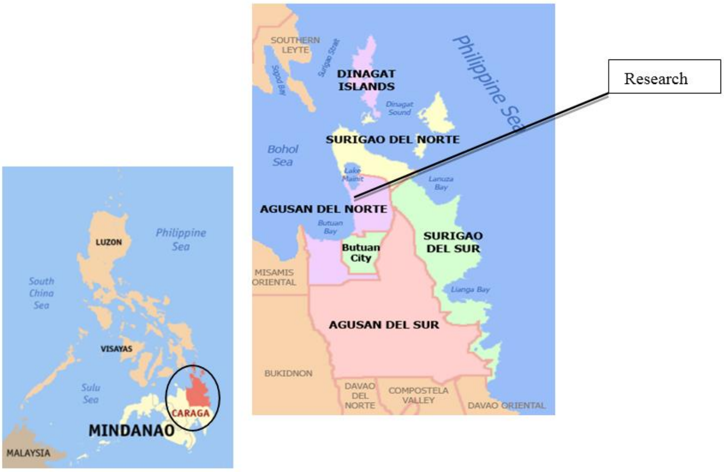

Fig. 1. Map of Caraga Region, Philippines showing the research site in San Roque Metals Inc. (SRMI)

The mining company has been operating in the site for over ten years. In designing its mine rehabilitation plan, native plant species are recommended to be included to restore the natural ecological dynamics in the area. The survey, therefore, focused on identifying plant species that grow in the lateritic soil of SRMI mine sites with potential for cultivation as ornamental.

Sampling was done in the mine site following a random layout across the area (Table 1). In every slope, stations were established at a 5-meter distance from each other. A 2×2 meter quadrat was used as the unit of sampling in every station. All plant species within the quadrat were listed down. In collecting plant samples, only the shoot part (containing the leaves or twig) were taken from the trees. For small plants, whole plant samples were collected. Each sample was placed in a paper bag and properly labeled according to station and slope.

Table 1. The sampling stations in both disturbed and undisturbed areas in the SRMI mine site

Station	Disturbed Area Location	Undisturbed Area Location
Upper Slope$_1$	N 09° 12’ 32.1” E 125° 32’ 13.0”	N 09° 12’ 30.5” E 125° 32’ 18.0”
Upper Slope $_2$	N 09° 12’ 32.0” E 125° 32’ 13.1”	N 09° 12’ 30.5” E 125° 32’ 17.7”
Middle Slope	N 09° 12’ 31.9” E 125° 32’ 13.2”	N 09° 12’ 30.4” E 125° 32’ 17.6”
Lower Slope$_1$	N 09° 12’ 31.7” E 125° 32’ 13.3”	N 09° 12’ 30.4” E 125° 32’ 17.4”
Lower Slope$_2$	N 09° 12’ 31.6” E 125° 32’ 13.4”	N 09° 12’ 30.3” E 125° 32’ 17.3”

Soil samples were collected from the various sampling stations in the mine site. The samples were brought to the laboratory for analysis. The plant samples were identified and recorded following the taxonomic classification and identification procedures. After identifying the samples, these were air-dried before laboratory analysis for iron and nickel contents in the leaves.

Results and Discussion

Plants in the disturbed and undisturbed area

The number of plant species collected in the disturbed area was lesser compared to the undisturbed part. Most of the species found in the undisturbed area are trees. There are more plants categorized as under-flora found in the undisturbed area compared to the disturbed area. Although under-flora species are present in the disturbed areas, only a few were observed since there are few trees also that exist. The existence of the under-flora is also generally important in improving the soil properties [11]. In nickel mines where the soil is highly mineralized, only shrubs, ferns and grasses are generally found. These shrubs and ferns have potentials for use as ornamental plants. These plant species play a very important role in protecting the soil from erosion. Revegetation of the mined-out areas is necessary to restore the natural ecological dynamics in the ecosystem. This program can be carried out using plants selected by their ability to survive and reproduce under severe conditions [5].

In the undisturbed natural habitats within the mine site, plant species that tolerate high levels of nickel and iron grow and become part of the landscape. There were 30 plant species collected in the undisturbed area, particularly in the middle and upper slopes (Table 2). In the disturbed area, organic fertilizer and other soil amendments were added to make the soil favorable for plant growth. However, only very few of the species that exist in the undisturbed area survived in the mined-out area. A program to utilize plant species existing in the undisturbed area to rehabilitate the mined-out area may hasten ecosystem restoration since these species are adapted to the conditions of the soil.

Table 2. Floral species recorded in undisturbed areas of the mine site

No.	Scientific Name	Family
1	*Arachis duranensis Krapov. & W.C.Greg.*	Fabaceae
2	*Canarium asperum Benth spp.*	Burseraceae
3	*Crypteronia paniculata Blume*	Crypteroniaceae
4	*Dacryodes rostrata (Bl.) H.J. Lam*	Burseraceae
5	*Davallia solida (Forst.) Sw.*	Burseraceae
6	*Decaspermum froticosum Forst*	Myrtaceae
7	*Dicranopteris linearis L.*	Gleicheniaceae
8	*Ficus ulmifolia Lam.*	Moraceae
9	*Flagellaria indica L.*	Flagellariaceae
10	*Glochidion canescens Elmer*	Phyllanthaceae
11	*Gmelina arborea Roxb.*	Verbenaceae
12	*Gnetum gnemon L.*	Gnetaceae
13	*Imperata cylindrica (L.) Beauv.*	Poaceae
14	*Leucosyke capitellata L.*	Urticaceae
15	*Macaranga tanarius (L.) Muell. Arg.*	Euphorbiaceae
16	*Melastoma malabathricum L.*	Melastomataceae
17	*Memecylon ovatum Sm.*	Melastomataceae
18	*Mimosops elengi L.*	Sapotaceae
19	*Morinda bracteata Roxb.*	Rubiaceae
20	*Neonuclea media (Haviland) Merill*	Rubiaceae
21	*Nephrolepis biserrata (Sw.) Schott.*	Nephrolepidaceae
22	*Ormosia surigaoensis Merr.*	Fabaceae
23	*Pandanus tectorius*	Pandanaceae
24	*Polyalthia elongate Merr.*	Annonaceae
25	*Pteridium aquilinum L. Kuhn*	Dennstaedtiaceae
26	*Saccharum spontaneum L.*	Poaceae
27	*Sandoricum vidalii Merr.*	Meliaceae
28	*Syngonium podophyllum Schott.*	Araceae
29	*Swintonia acuminate Merr.*	Anacardiaceae
30	*Trema orientalis L.*	Ulmaceae

Characteristic of soil in the disturbed and undisturbed area of the mine site

The texture and pH of the soil in the disturbed and undisturbed areas are relatively the same (Table 3). The soil pH was slightly acidic where crops prefer to grow. The organic matter (OM) was very deficient in both disturbed and undisturbed areas. The soil in the sampling sites, in both the disturbed and undisturbed areas, have a medium texture except for the lower slope in the undisturbed area where the soil is heavy textured. The soil pH is slightly acidic to neutral, ranging from 5.50 to 7.05. For the macronutrient composition, the soil is generally very deficient in organic matter (OM) as the analysis showed the % OM ranging from 0.6 to 2.0 particularly those in the disturbed sites. However, in the undistrubed sites, the soil has an OM ranging from 2.2% to 3.5% which is considered as deficient. For the P composition, the soil in both disturbed and undisturbed areas are all very deficient, with only 1-5 ppm. The K composition of the soil in the mine site is considered deficient, with those in the upper slope of th disturbed areas having only 16 ppm to 32 ppm. Some slopes have K composition ranging from deficient to modrately deficient, with K analysis ranging from 40 ppm to 72 ppm.

The soil OM is important as it plays a key role in both the availability of micronutrients and the dilution of toxicity by heavy metals [12]. This component also affects the physical properties of the soil. Soil with a low OM content tends to become rigid, compacted and cloddy. Based on soil analysis, the soil in SRMI is not favorable in growing crops due to deficiency of the major nutrients and high concentrations of heavy metals. The high concentration of heavy metals in the soil generally causes stunting of plant growth, reduced reproductive performance, and low productivity [13]. Growth reduction is a result of changes in physiological and biochemical processes in plants growing on heavy metal-polluted soils.

Plants that grow in different elevations in the mine site

The undisturbed area has a higher number of plants species compared to the disturbed area (Table 4). A total of 8 different species was found in the undisturbed area while only four species were collected from the disturbed area. The most common species found in the area are mostly under-flora species. In all elevations, *Pteridium aquilinum*, *Saccharum spontaneum*, and *Imperata cylindrica* were commonly noted. The area has high contents of iron and nickel. Thus these plant species are probably tolerant of these heavy metals. The effect of heavy metal toxicity on the growth of plants varies according to the particular heavy metal involved in the process. The direct or indirect effects of toxic metals to the growth of plants lead to the decline of plant growth, and sometimes it can cause the death of plants.

The same plant species dominating in the upper slopes are common in other elevations: *Imperata cylindrica*, *Saccharum spontaneum*, *Pteridium aquilinum*. The presence of these plants may have important effects on the ecosystem where they exist. Also, the classification of natural ecosystems into potential plant communities and habitat types is important for the long-term management of the natural resources. Discovering and understanding the association of biotic and abiotic components of an ecosystem is critical for understanding interrelationships in the ecosystem (14]. Thus this information is crucial in mine rehabilitation planning.

The distribution of various plant species is also an indicator of the ecosystem capacity to support life. In the sampling, *Sandoricum vidalii Merr., Pteridium aquilinum (L.) Kuhn, Imperata cylindrica (L.*) *Beauv.,* and *Saccharum spontaneum L.* are the dominant plant species in the disturbed areas. On the other hand, *Leucosyke capitellata L., Melastoma malabathricum L, Pandanus tectorius, Ormosia surigaoensis Merr., Macaranga tanarius (L.) Muell. Arg., Dicranopteris linearis L.* are recorded in the undisturbed areas distributed in the lower, middle and upper slopes. In both disturbed and undisturbed areas in the lower slope, *Pteridium aquilinum,* an aggressive fern species that spreads via rhizomes, is the most common species. Plants are important to enhance the soil quality which also contributes to the dynamics of the ecosystem. Since these plant species are observed commonly in the area, they are tolerant of the adverse environment in the area. Their dominance in iron-rich soil has already prompted the locals to use it as an indicator of iron and nickel in the soil.

Nickel and Iron accumulation in plant samples

Heavy metals are naturally present in the soil. The anthropogenic activities may increase the concentration of these elements to amounts that can have harmful effects on both plants and animals. The effect of heavy metal toxicity on the growth of plants varies according to the particular heavy metal involved in the process [13]. However, certain plants can accumulate heavy metals without being harmed and thus are called hyperaccumulator plants [15]. Several functions of elemental hyperaccumulation have been proposed including plant defense [16].

The result for the laboratory analysis for plant samples collected from SRMI mine sites indicated that the amount of iron ranges from 3,042.69 to 48,567.11ppm, which is very high (Table 5). The amount of nickel, on the other hand, ranges only from 161.09 to 1,416.87. Among the plant samples, *Crypteronia paniculata* has the highest value of 48,567.11 ppm for iron and 1,416.87 ppm for nickel. This suggests that this species is a good candidate for rehabilitation of the mined out area. This is followed by *Leucosyke capitellata,* with values of 1,194.06 for Nickel and 19,906.86 for iron.

Table 5. Nickel and Iron content in the leaves of plant samples from the mine site of SRMI

Plant Samples		Actual concentration of Nickel (mg/kg or ppm)	Actual concentration of Iron (mg/kg or ppm)	Rank
Scientific Name	Plant Type			
Canarium asperum	Tree	257.04	7,170.26	11
Sandoricum vidalii	Tree	552.11	15,663.39	6
Decaspermum fruticosum Forst	Shrub	161.09	3,042.69	17
Leucosyke capitellata	Shrub	1,194.06	19,906.86	2
Flagellaria indica L.	Vine	973.38	36,169.10	3
Pteridium aquilinum	Fern	184.32	6,204.78	16
Gmelina arborea	Tree	191.34	5,401.99	15
Gnetum gnemon L. var. gnemon	Tree	233.74	7,785.22	12
Melastoma malabathricum	Shrub	434.76	7,032.30	8
Pandanus tectorius	Tree	817.10	27,596.75	4
Crypteronia paniculata Blume var.paniculata	Tree	1,416.87	48,567.11	1
Ormosia surigaensis	Tree	309.31	7,067.14	9
Neonuclea media	Tree	755.21	11,230.79	5
Mimusops elengi L.	Tree	437.71	6,009.37	7
Ficus ulmifolia	Shrub	138.54	3,885.77	18
Ventilago dichotoma	Tree	197.26	5,189.37	14
Macaranga tanarius	Tree	200.51	3,624.19	13
Dicranopteris linearis	Fern	263.41	3,807.38	10

** Analyzed at the Caraga State University Chemistry Laboratory*

Plant species with the capacity to accumulate heavy metals are known to be tolerant to the adverse conditions in metal-rich soil environments. These species are, therefore, very valuable phytogenetic resources that can be used in the rehabilitation of the mined land. The use of local plant species for rehabilitation is recommended to boost the rehabilitation program. Planning for rehabilitation of mined land is a very complex process. Measuring the effectiveness of reclamation needs to be evaluated more than the mere presence of vegetation of the site. Several parameters must be considered in order to determine the state and functionality of the reclamation process in order to have sufficient information. Soil biological processes and the rearrangement of soil particles into aggregates are the key factors related to the soil. In mine rehabilitation, technologies in planting and landscape architecture are necessary especially if the end use plan of the area is for ecotourism. Considering the amount of nickel and iron uptake of certain plant species, these can be used for rehabilitation of the nickel mined out area.

Conclusion

The 30 plant species in the mine site of SRMI show tolerance to the lateritic soil with high nickel and iron concentrations. Of the plant species, *C. paniculata* and *L. capitellata* were found to have the highest actual concentration of nickel and iron. The presence of fern species in the undisturbed area indicated their prospective use in mine rehabilitation due to their growth habit which can modify the microclimate and allow the soil-inhabiting arthropods to thrive and help in the nutrient cycling which can contribute in the overall ecosystem restoration. These plants have huge value as ornamental materials. The plant species that show high tolerance to heavy metals and have ornamental potentials are good for the revegetation program of the mined out area.

Acknowledgement

The authors thank the San Roque Metals Inc. (SRMI) for allowing the study in its mine site and the Department of Science and Technology-Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD) for the funding support.

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Received: Octomber 02, 2018
Accepted: October 10, 2019